

## Section of Comparative Medicine.

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### The Relation of Wild Animals to Certain Diseases of Man.

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IN the highly civilized state to which the majority of mankind has attained at the present day, it is only in the tropics, where he still exists in a more or less primitive state, that an intimate contact with the indigenous fauna is possible; and it is therefore mainly in tropical countries that we find him a prey to disease germs which normally infest wild animals. Probably, at one time, some of these parasites were more widely spread than at present; but the exact manner in which they originated still remains a matter for speculation. It is probable, too, that primarily their virulence was much greater, but that, in process of time, each species of animal became tolerant of each particular parasite, so that eventually a state was attained in which host and parasite existed on terms of harmony; this is a condition such as we understand by the "reservoir" state; but it is one in which the parasite retains its virulence for non-immune individuals.

There is hardly a subject which so strongly supports the Darwinian hypothesis of the origin of man as this, and it is one which Darwin himself, had he been familiar with the details, would doubtlessly have exploited to the full. That man is in fact but part and parcel of the great scheme of Nature and heir to the parasitic infections of animals around him, and a victim to parasites which fulfil their purpose by destroying or checking the numbers of immigrant species, appears to us now to be a self-evident fact.

For the passage of these disease germs from one host to another prolonged and intimate contact is necessary, but when once this chain of contact is broken, the parasite is no longer able to attain the different stages necessary for its evolution and must perish. But in the process of civilization certain animals such as the ox, the pig and dog, have during domestication inherited diseases from their wild ancestors and have continued to transmit them to man, who in turn has become, in some cases, the necessary intermediary host. The theories as to how these disease germs arose in the first instance, and how they became adapted to man, we will discuss at a later stage.

#### TRYPANOSOMIASIS.

The trypanosomes are blood parasites of many diverse orders of the animal kingdom; they attain their greatest development in the continent of Africa, where they exist as apparently harmless commensals in the blood of the larger ruminants, especially the antelope of that country. These organisms have become adapted to very varied conditions, and species peculiar to birds, reptiles, fishes and amphibia are known.

In Africa, man has become infected with only two species which infest mammalia, viz., *Trypanosoma gambiense* and *Trypanosoma rhodesiense*. In South America a perfectly distinct species, *Trypanosoma cruzi*, has been found parasitic in man in certain limited areas in Brazil and Venezuela.

*Trypanosoma gambiense* is responsible for the best known form of sleeping sickness in man; it is indigenous and peculiar to Central Africa, where it has spread as an epidemic over a vast area during the last half century. The range of this disease is coterminous with that of the tsetse-fly, *Glossina palpalis*, which acts as its definite host. Under laboratory conditions, this trypanosome can be conveyed to most domestic animals, to monkeys and the larger antelopes, but there is a good deal of evidence that at the present day it is essentially a human infection and is spread by the agency of man to man. There is, however, one antelope which, from its habits and its range, is admirably adapted to act as a reservoir of *Trypanosoma gambiense*. This is Speke's sitatunga (*Limnotragus spekei* [2], or *Tragelaphus selousi*), of which naturally infected individuals have been found by Duke [3] on the Sesse Islands in Lake Victoria. This very handsome antelope stands 36 in. at the withers. The buck possesses fine spirally twisted horns. In ground colour it is of a uniform greyish-brown, but the head is adorned with white ocular and cheek spots and a white chin. The type species comes from the Sesse Islands, but minor variations have been traced throughout its range which extends through the lakes and swamps of Eastern and Central Africa. This species, which was discovered originally by Speke in 1861, is a very wary antelope, and as it lives in dense and impenetrable papyrus, it is rarely seen or shot by Europeans. It occurs in the greatest numbers on the islands already mentioned, which from the year 1900 onwards were ravaged by sleeping sickness to such an extent that in 1909 the inhabitants were moved to the mainland. Five years [4] subsequently the tsetses of the island were still found to be infected with *Trypanosoma gambiense*, a fact which was attributed by Duke to the presence of infected antelopes of this species. The hoofs of this antelope are long and widely splayed, an admirable adaptation to its habitat, but since the removal of the population from the islands already referred to it has come to live on dry land and its hoofs have become much shorter and modified accordingly.

The sleeping sickness of man produced by *Trypanosoma rhodesiense* does not differ essentially from that produced by the former species. On the whole the illness runs a much more rapid course, and is accentuated by severe febrile paroxysms. Fatal symptoms usually supervene within a year of infection. The organism is much more resistant to drug treatment, especially the arsenical compounds, which have been found efficacious in *Trypanosoma gambiense* infections. This disease has a curious distribution in Central Africa, for it corresponds very closely to that of *Glossina morsitans*—the tsetse of the big game; but it never appears to spread in man in epidemic form. This sleeping sickness occurs in North-Eastern Rhodesia, especially in the Luangwa Valley, in the south-eastern portion of Tanganyika territory, in Nyasaland in the region south and west of the lake. Whilst present in the blood of man, *Trypanosoma rhodesiense* is indistinguishable from *Trypanosoma gambiense*, but it was differentiated by Stephens and Fantham in 1910 by the fact that when inoculated into laboratory animals, especially the rat, a change takes place in the trophonucleus, which assumes a position close to the kintonucleus or sometimes posterior to it. Subinoculations into laboratory animals are invariably successful and run a rapid and fatal course, in contradistinction to what happens in the case of *Trypanosoma gambiense*.

The part played in the dissemination by the wild game of this parasite to man has been the subject of a great diversity of opinion.

The trypanosome of the big game in this area, *Trypanosoma brucei*, belongs to the polymorphic group of trypanosomes and is indistinguishable, morphologically, from *Trypanosoma rhodesiense*. Yorke, Kinghorn, and Bruce believe that under certain conditions *Trypanosoma brucei* can be inoculated into man and produce a *rhodesiense* infection, but others, notably Kleine, Taute and Huber, by experiments upon themselves, either by injecting themselves with *Trypanosoma brucei* infected blood, or

through being bitten by infected *Glossina morsitans*, without contracting the disease, consider them specifically distinct. It is, however, clear that a large proportion of the game must be infected with *Trypanosoma rhodesiense*. Waterbuck (Weck [5] 1914) have been infected with human *Trypanosoma rhodesiense* and have shown no signs of disease, though this animal's blood produced in turn a fatal infection in monkeys and dogs.

Three species of antelopes are usually regarded as reservoir hosts of *Trypanosoma rhodesiense*. The handsome common waterbuck (*Cobus ellipsiprymus*, Ogilby) [6] has a wide distribution in Central Africa; its range extends from the Limpopo River northwards to Tanganyika Territory and Kenya, as far north as Somaliland; on the west it is replaced by allied species. The waterbuck is readily distinguished from others by the white ribbon which passes over the rump and is carried down the thighs on both sides. Although it has the appearance of a clumsy animal, it becomes elegant and sprightly when excited. It can travel at a fast gallop and is difficult for man to follow, though falling an easy prey to lions and leopards.

The waterbuck is always found in greatest numbers on large swampy plains overgrown with coarse grass, tall reeds and papyrus, where in the wet season it is impossible to get at it. It revels in almost inaccessible swamps where only elephants, buffaloes and reedbucks care to stay. For this purpose Nature has provided the waterbuck with a tougher hide and coarser hair than any other of its kind, so as to protect it against the sharp fronds of papyrus and other water plants. From the nature of its habitat it will be understood that the extermination of the species would form an almost impossible task.

The reedbuck (*Cervicapra arundinum*, Bodd) [7] is a comparatively large antelope measuring some 36 in. at the withers, and in general colour greyish-fawn. It has a thick and bushy tail reaching half-way to the hocks, and handsome evenly divergent horns which curve backwards and upwards. The female resembles the male, but is hornless. There are at least five species of varieties of the reedbuck. Rare in the Transvaal and Bechuanaland, it is still plentiful around Lake Nyasa, and extends as far north as Mozambique and on the west to Angola. This antelope is easily approached, its gallop is slow and irregular, and it is said to be one of the easiest of the South African antelopes to shoot. When alarmed the herd give vent to shrill screams and bound off, kicking up their hind legs and tossing their tails like rabbits. It has not been found possible to keep this species in captivity.

There are many species of *Duikerbuck*; the majority are at home in the dense bush of Western Africa. The common duiker, *Cephalopus grimmii* (Linn.) [8] was originally described by Grimm in 1686, and has a wide distribution throughout the *rhodesiense* sleeping sickness area, being found throughout South Africa, along the east coast as far north as Somaliland. It stands 23 in. height, the general colour of the body being pale greenish-brown. Horns are normally present only in the male, in whom they attain a length of 5 in. This antelope is called the "duiker," or diver, not from its habit of going into water, but from its manner of ducking and diving quickly into bushes when alarmed. In the Cape it is frequently kept in a semi-domesticated state around farmhouses, but does not thrive in captivity in this country.

#### SOUTH AMERICAN TRYPANOSOMIASIS.

Caused by *Trypanosoma* (*Schizo-trypanum*) *cruzi*, this disease runs a very different course, and has an entirely peculiar natural history. This parasite causes a chronic or acute disease in children, especially in certain districts of Brazil and Venezuela. The symptoms partake for the most part of a myxœdematous [9] character, with febrile disturbances and enlargement of the thyroid gland. The chronic stage may also be seen in adults, when it is characterized by organic syndromes, due to the involvement of the heart muscle, suprarenal glands, or nervous system. The parasite

occurs in the blood-stream in forms which are said to represent young individuals which have just escaped into the circulation, and in broader ones representing an older generation. Multiplication of the parasite by leishmania-like forms takes place in most of the tissues of the body, especially in the skeletal and cardiac muscles.

The infection is disseminated by curious reduviid bugs, the most important of which is *Triatoma megista*; this bug constitutes the definitive host of the parasite. A large proportion of these insects are found to be naturally infected; they live entirely on wild animals, such as armadilloes, whose burrows they frequent, but certain species have become domesticated. Both the larvæ and the nymphs of this insect can become infected with *Trypanosoma cruzi*. Considering the wide range of these bugs, and the facts (1) that certain species are found naturally infected with this trypanosome in Argentina, (2) that an allied form, *Triatoma protracta*, is found in a similar condition in the United States, (3) the ease with which the parasite can develop in other insects (*Cimex* and *Ornithodoros*),—it becomes difficult to comprehend the limited geographical distribution of this disease as it occurs in man. The trypanosome is probably under natural conditions conveyed to animals upon which the *Triatoma* feeds, and they therefore constitute the reservoir host. The most important are the armadilloes. The long-tailed armadillo (*Tatusia novemcincta*) [10] appears to be the natural host of *Trypanosoma cruzi*. This species inhabits Mexico and Central America, where it lives in burrows, but in Nicaragua is often kept tame in houses to protect them from invasion by ants. In Guatemala it abounds in primeval forests up to an altitude of 5,000 ft.; there it is much hunted for its flesh, which Dampier described as very sweet and tasting like that of a land turtle. When disturbed this armadillo rolls itself up like a hedgehog. Armadillo burrows are found underneath the houses, and in the immediate vicinity of these, cases of the human trypanosomiasis were originally discovered in Brazil.

The "peludo" (*Dasypus sexcinctus*) [11], a much smaller animal, 18 in. in length, common in Brazil, is an omnivorous creature, particularly fond of carrion. It is said to possess a faculty of burrowing up to a decaying carcase, in much the same manner as that of the ground-beetle. *Dasypus* has a very short tail, which is shielded by distinct rings near its base.

The other natural hosts of *Trypanosoma cruzi* are entirely different animals. The first of these is *Azara's opossum* (*Didelphys aurita*) [12], a marsupial which has a very extensive range in South America, from Uruguay to Costa Rica. This opossum creates the same havoc amongst poultry in these countries as does the fox in Europe. Sleepy and drowsy in the day time, the opossums live in the roofs of houses in intimate contact with man, rarely showing themselves in the open. In the towns there are few houses which are not infested with these hideous beasts. Often the stranger is roused from his slumbers by the sound which is caused by these animals running over the roof, upsetting in their course dishes and other household utensils. If he makes inquiry as to the cause of the alarm, he receives as an answer "Señor, es el zoro" (zoro is a fox in Spanish).

The fourth reservoir host of this interesting parasite is a rock cavy (*Cavia* (*Cerodon*) *rupestris*) [13], which is indigenous in Brazil in rocky situations. It is usually found near rivers, but always in the higher parts of their course, where it seeks its retreat in holes and amongst rocky boulders. Superior in size to most other cavyes, and standing higher on its legs, it is remarkable for the softness of its fur. It is 14 in. in length, and its flesh is said to be well flavoured and much sought after by the Indians. Brumpt and Gomes found infected triatomas in the burrows of this rodent in a deserted spot ten miles from any human habitation.

The history of this trypanosome is of comparatively recent date and is remarkable, not only for its peculiar life-history, but from the circumstances surrounding its discovery by Chagas in 1909. This observer first found trypanosome-like flagellates in the hind gut of triatomas, and Cruz, on causing these insects to bite

a monkey, subsequently found trypanosomes in its blood. It was this discovery which led Chagas to search for the trypanosome in the blood of man; in this he was successful in discovering it in the blood of individuals living in the very houses from which the infected triatomas were at first derived; there also he found the parasite in the blood of cats.

#### LEISHMANIASIS.

Parasites of the genus *Leishmania* are intracellular organisms, which, from a study of their structure inside the human body, as well as of their development into a flagellated stage in artificial media outside the body, are shown to be in close affinity with the trypanosomes. The *Leishmania donovani* is the parasite responsible for a generalized disease in man, known as kala-azar, which has a peculiarly restricted geographical distribution, being found widely spread in India (especially in Assam and the United Provinces), China (Central Provinces and the Valley of the Yangtse Kiang), Central Africa (Sudan, West Abyssinia and Tchad territory), along the shores of the Mediterranean basin, and in the Ægean Islands. In this latter area it is associated with a similar infection in dogs. The peculiarities of its distribution would seem to indicate that it is in some manner connected with the presence of some free-living reservoir host. The parasite can be communicated, though with difficulty, to dogs, cats, jackals, monkeys, rats and mice, but it is only lately that a really susceptible animal has been discovered. Smyly and Young have found that the hamster (*Cricetus griseus*) [14] is very readily infected; that in these animals an enormous proliferation of the parasite takes place. Apparently, in spite of the great numbers of the parasites, the health of these animals is not seriously affected. It therefore appears possible that this small rodent, or some similar animal, constitutes the reservoir host of the *Leishmania*, and that the actual transference of the parasite to the human body takes place through the agency of a small biting fly, such as the sand-fly, *Phlebotomus*.

The hamster, *Cricetus* (*Cricetulus griseus*, Milne-Edwards) [15] is a little species of the size of a field-mouse, and is common in the country districts round Peking and extends into Chinese Mongolia. This little creature makes extensive burrows, frequenting cornfields and destroying quantities of grain. Greyish-brown in colour, it is pale beneath, has large black eyes, and a median dorsal brown stripe.

#### WEIL'S DISEASE, AND INFECTIONS WITH LEPTOSPIRA.

A severe and fatal form of jaundice, associated with fever and a high mortality, has been known in Europe since it was first described by Weil in 1886. Its close resemblance on clinical grounds to yellow fever has long been recognized, so much so that, long before the true ætiological agent was discovered, it was known as Mediterranean yellow fever. The parasite, *Leptospira icterohæmorrhagiæ*, was discovered in 1916 [16] by several Japanese investigators, and they were able to reproduce a typical jaundice in guinea-pigs. It has since been shown that this *Leptospira* is normally a parasite of a rat (*Rattus norvegicus* and *Rattus alexandrinus*) in Europe, and of the field vole (*Microtus montebelloi*) in Japan. In these animals apparently the organism lives in the urinary tubules of the kidney and is excreted in the urine. Thus it happens that large numbers of apparently healthy rats harbour this parasite. Foulerton [17] and, later, Stephenson and Balfour [18] found that no less than 22·6 per cent. of London rats are thus affected. Other wild animals can contract the infection as well. Our honorary secretary, Mr. George Dunkin [19], recently found a young fox naturally infected near the laboratory at Mill Hill. This disease may also possibly be conveyed to carnivora in captivity through eating infected rats. Apparently this recently occurred in the London Zoological Gardens, but since Dr. Ververs has forbidden the feeding of these animals with rats the disease has disappeared. Last year it was proved by Okell [20] and others that a naturally

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acquired typhoid-like illness known as epizootic jaundice in foxhounds is also due to the same parasite. To add to the interest of this subject it has been found that spirochætes of the *Leptospira* type are widely distributed in water [21], especially that of contaminated wells and rivers, and that small outbreaks of Weil's disease have recently been reported in man from Scotland (East Lothian and Edinburgh) and the Midlands. The probability is that this disease is normally conveyed by infected water contaminated by rats, which constitute the reservoir host of the disease. It is a matter of considerable interest, and a subject for speculation, as to why the closely related *Leptospira icteroides*, the organism of yellow fever, should appear to be a parasite of man only. Arguing by analogy from what we know of Weil's disease, which yellow fever so closely resembles in its clinical course, one would surmise that this organism was widely distributed amongst monkeys and other small mammals in those countries (South America and West Africa) in which yellow fever is endemic. The reservoir host, if other than man himself, has still to be discovered.

There still remains to be mentioned a leptospiral disease which has recently been described. This is the seven-day fever of the Japanese. The organism was first discovered in 1918 [22] by Ido, Ito, and Wani and named *Leptospira hebdomadis*; it is apparently a parasite, like *Leptospira icterohæmorrhagiæ*, of the urinary tract of the common field vole, *Microtus montebelloi*, Milne-Edwards. Very little is known about the fever in man, except that it lasts seven days and does not appear to be a fatal disease.

The *Microtus* [23], wrongly called in text-books a field mouse, is really a stump-tailed vole, which is common in country districts in Japan, and is closely allied to similar voles which occur in China and Tibet. There is little to be said about its habits, except that it burrows and feeds upon roots and grain in much the same manner as do similar creatures in other countries.

#### RAT-BITE FEVER.

This is a world-wide disease, but it appears to be specially common in Japan.

Following on the bite of an infected rat, sometimes after a prolonged incubation period, a lymphangitis supervenes which implicates the glands of the area involved. Then follow many short attacks of fever coinciding with an exacerbation of local symptoms.

The organism, *Spirillum minus*, was formerly thought to be a spirochæte, is very minute,  $1.5\ \mu$  to  $6\ \mu$  in length, and can be found in the blood, as well as in the lymphatic glands, during the height of the disease. This fever is transmitted by the brown rat (*Rattus rattus* and *Rattus alexandrinus*), and the organism is probably identical with *Spirillum laverani* and with *Spirillum muris*, which are commonly found in the blood of rats and mice. It is said that the disease can also be conveyed by the bite of a ferret or by that of the domestic cat. The wild cat has also been incriminated. *Felis catus*, Linn. [24], is said to still exist in the Highlands of Scotland in a purely wild state, but this statement is doubted by many authorities, as it appears to have intermingled with the house cat wherever that familiar animal has penetrated.

#### ROCKY MOUNTAIN SPOTTED FEVER.

This is not a disease of the tropics at all; it is, however, peculiarly associated with the presence of wild animals. A typhus-like disease with a high mortality rate has long been known as "spotted fever," "blue disease," and "black fever"; and to be endemic in limited districts of Montana and Idaho and Wyoming. It has also been reported from the States of Utah, Nevada, Oregon, Colorado, and Washington. This fever is virulent, especially in the spring months of the year in the district of Montana known as the Bitter Root Valley. The causative organism belongs to that

rather nebulous group, the *Rickettsia*, and is known as *Dermacentor rickettsi* [25]. It is conveyed by the bite of a tick peculiar to that region, known as *Dermacentor venustus*. It is only the adult tick that attacks man, but it commonly infests the Rocky Mountain goat, the badger, lynx, bear, coyote, and other animals that inhabit that region. The larval and nymphal stages of the tick develop principally on the ground squirrel (*Citellus columbianus*) and the woodchuck (*Marmota flaviventer* nosophora, Howell). The last two rodents are considered to be the main reservoir hosts of the *Rickettsia* and, although a certain proportion are capable of infection in the laboratory, it is thought that they may develop the disease in a mild form under natural conditions. Of the larger animals the tick most favours the Rocky Mountain goat (*Oreamnus montanus*) [26]. It is not really a goat at all, but is most nearly allied to the serows, a rare animal at the present day, as it only exists where strictly preserved. The American badger (*Taxidea taxus*) resembles its European relative, with the difference that its diet is more carnivorous. The black bear (*Ursus americanus*), and the lynx (*Lynx uinta*) hardly call for comment. The coyote (*Canis latrans*, Say) is a small slinking wolf-like creature which differs from its European congeners in living in burrows in the plains.

The Columbian ground squirrel (*Citellus columbianus*, Ord) [27] is closely allied to the chipmunk, and is an intelligent little creature like its near relative; it lives amongst the birchwoods, where it digs its burrows in such a manner as to avoid attracting the attention of its enemies. In order to do so it removes the earth in its cheek pouches and carries it to a considerable distance. In winter the ground squirrel hibernates and in this state it probably harbours the virus of Rocky Mountain fever, so that it is able to convey the disease shortly after its spring awakening.

The woodchuck (*Marmota flaviventer*) is really a marmot, about 2 ft. in length; it is a thick-set creature with short legs and a stout bushy tail. It is grizzly or yellowish-grey in colour and hibernates all the winter long. Being vegetarian in diet, it lives in woodlands, never in the open plains, and is said to be the least industrious of all animals, to show energy only when digging its burrows, which may be 50 ft. or more in length.

#### PLAGUE.

Plague is essentially in the first place a disease of rodents and not of man. As Macarthur has so lucidly pointed out recently, much suffering would have been saved in the City of London had this been recognized in the Middle Ages.

Although the rat is the main reservoir of plague, many other rodents in many other parts of the world play a not inconsiderable part.

There are, as is well known [28], two species of domestic rat, of which the black rat (*Rattus rattus* Linn.) is the more important in the spread of the disease. The old English rat, as it is called, is rapidly vanishing from this country, being ousted by the more virile North European species (*Rattus norvegicus*, Berkenhout), which was apparently imported into Western Europe in the year 1716 as a result of a visit by the Russian Fleet. The black rat in India, in Burma, and in fact in the tropics generally, lives more closely in association with man; it is essentially an arboreal or climbing animal and rarely burrows; hence, when it infests buildings or huts, it is found usually in the walls, ceilings or roof. It drinks little and seldom enters the water voluntarily and it is the common rat on ships. In most cases it reaches or leaves the ships by clambering along the cables whilst the ships are in dock. Its dietary consists mostly of grain, and it is a much cleaner feeder than *Rattus norvegicus*. In appearance it differs also from *norvegicus* in its more slender build and large transparent ears. The weight of the adult is 8 oz.

There are several races of *Rattus rattus* which have been distinguished. One variety with reddish-black and pure white underparts is known as *Rattus rattus frugivorus* and is common in the Mediterranean area. The Alexandrine rat (*Rattus*

*rattus alexandrinus*), with brownish-grey back and dingy coloured abdomen, is found in Asia Minor and North Africa. *Rattus rattus rufescens* is the common Indian house rat and is distinguished by its smaller size, its long tail and the spinous hairs with rusty tips on its abdomen. These rats breed throughout the year, gestation lasting twenty-one days, the average litter being five or six.

The brown rat (*Rattus norvegicus*) is distinguished by its larger size, its heavier and clumsier build and by its blunter muzzle. The ears are small and opaque; the tail noticeably shorter than the head and the body. The weight of the adult is about 17 oz. This rat is now developing a melanistic or black variety which was originally described in Ireland. Its home was originally temperate Asia. It is a water-loving and burrowing animal and is consequently far less agile than the former species, but it is far more voracious and cunning and is possessed of greater strength and fecundity. Usually exhibiting a shyness of man it is under normal conditions a less important carrier of plague than is *Rattus rattus*. *Rattus norvegicus* is a very rapid breeder, the litter varying from six to twenty-three, the average from eight to ten.

In various parts of the world other rodents are capable of replacing the rat in the spread of plague. In California, McCoy has shown that the Californian ground squirrel plays an important part, and that the plague bacillus is transferred by the flea (*Ceratophyllus acutus*) to rats and so to man. This ground squirrel (*Citellus grammurus beecheyi*, Richardson) [29] is in reality a spermophile and lives in burrows. In Southern Russia and the Caucasus other ground-squirrels (*Citellus*) are said to carry plague. These rodents are really a connecting link between the squirrels and the marmots. They are generally to be found in prairie-like regions, where they form an intricate system of burrows, at the mouth of which they are commonly to be seen standing upright and motionless. The common European species is *Citellus citellus* Linn., and is known in Russia as the "suslik." In Mongolia a subspecies known as *Citellus dauricus* plays a similar part. These animals hibernate throughout the winter and are responsible for the summer outbreaks of pneumonic plague in Mongolia and Manchuria. In these regions, too, the common house mouse, *Mus musculus*, is held to be responsible for winter outbreaks of plague, though it does not appear to play a dominant part in other regions. In North China, Siberia and Manchuria the Mongolian marmot or "tarabagan" (sometimes called tarbagan, or sarabagan (*Marmota bobak*, Müller) [30] has been held to be responsible for many serious outbreaks of pneumonic plague. These marmots are of a large size and strong build. They are characterized by the rudimentary character of the thumb, their small eyes and ears; the tail is bushy and comparatively short. In length (exclusive of tail) they are 15 to 18 in., and 9 to 12 lb. in weight. They make large, deep and intricate burrows where they hibernate. The mounds of earth thrown up by generations of tarabagans are known as "bootans," and are characteristic of the region they inhabit [31]. The flesh of the tarabagan is eaten by the Mongols, or "Buriats," and its fur is in much demand, being sold after drying and curing as imitation sable or seal [32]. This creature is credited with the faculty of harbouring the plague bacillus in its body during hibernation, and thereby causing outbreaks of pneumonic plague amongst the hunters, who live under miserable conditions huddled together in underground hovels during the autumn and winter. The "Buriats" are said to be well aware of the danger of handling sick tarabagans, the infected animals being recognized by ceasing to bark and by being ejected by their healthy companions when they attempt to crawl back into their burrows.

In India, besides the rat, an insectivore, the musk shrew, *Pachyura cærulea* [33], plays a part in conveying plague. This shrew is about 6 in. in length, with a tail of 3½ to 4 in. It is coloured uniformly with a bluish-ash or pale grey hue, slightly tinged with red, the naked parts being flesh coloured. Commonly called the "musk rat," it frequents houses at night time, running about the rooms hunting for cockroaches or other insects, and uttering, while so doing, a sharp, shrill cry. It is popularly



believed in India that the musky odour emitted by this shrew possesses such volatile and penetrating powers that it will actually permeate the cork of a bottle and taint the fluid within.

The bandicoot rat (*Bandicota gigantea* [34]) is also susceptible to plague. This is a large rat 15 in. in length, with a tail of 13 in. and weighing about 3 lb. when fully adult. The incisor teeth are peculiar, being olive green at their base and yellow at their extremities. It is a well-known rat throughout India and Ceylon; being of a large size it shows fight when cornered and grunts like a pig. Where European gardens are cultivated, as in Newera Eliya, Ceylon, it causes considerable damage amongst the potatoes and peas.

In South Africa, plague [35] [36] [37] has spread amongst a number of rodents. When first introduced in 1901 it was apparently confined to the domestic rats. Further outbreaks in 1903, 1914 and 1918, led to the suspicion that other rodents were concerned. Some of them are responsible, as is the Cape hare, for transmitting the infection over a considerable area, but the chief part is played by small rat-like animals known as the gerbilles; of these there are numerous species in South Africa.

The first is known as Lobengula's gerbille, *Taterona lobengulæ* [38]. Gerbilles are distributed all over South Africa south of the Sahara. They are all very closely related and are probably equally susceptible to plague. This particular species has been singled out by the health authorities in South Africa. It receives its specific name because it inhabits the former territory of Lobengula, the Matabele king. It is about 5½ in. from the nose to the root of the tail, the latter being 1 in. longer than the body. The fur is light fawn on the back, finely grizzled with dull black; the sides are pale fawn, the under parts are white and strongly demarcated. Although a gerbille, this particular species has the habit and structure of a rat. Other species probably involved are known as the Cape gerbille (*Taterona afra*) and Brant's gerbille (*Taterona brantsi*).

The white-nosed rat (*Rattus coucha*), sometimes called the multimammate mouse, is in appearance something between a rat and a mouse, and living in close association with the gerbilles, it is also frequently attacked by plague. This species is distributed throughout South Africa, and its range extends beyond the Equator to the Sahara. It is found in situations which afford abundance of cover, such as thick scrub. It is a house dweller and is often trapped in buildings and outhouses. The tip of its nose, as its name indicates, is white.

The Springhaas, or Cape jumping hare (*Pedetes caffer*), is a much larger animal, the size of a rabbit, and by far the largest of the jerboa family. It is common throughout the Cape Province. It is sociable in its habits and forms an intricate series of burrows in which a good many families take up their abode. When alarmed and travelling at full speed, it races like a kangaroo, each leap covering 8 or 9 ft. It is nocturnal in its habits and multiplies very rapidly. It has many natural enemies and is preyed upon by the Cape eagle owl. This species can travel 20 to 40 miles in a single night; on this account it is of importance in the spread of plague.

Carnivores which prey on these rodents, especially when sick, such as the yellow mongoose (*Cynictus penicillata*) and the suricat (*Suricator suricator*), are also found to die of plague; when the faeces contain the remains of gerbilles, which they feed upon only when they are sick, it is taken by the health authorities as an indication that plague is endemic in that particular area.

In Senegal and West Africa a shrew (*Crocidura stampflii* [39]) is said to play a part in the dissemination of plague. It lives in native houses and probably has much the same habits as those of the Indian musk rat and plays a similar rôle.

In England [40] the rabbit and hare were found naturally infected with plague in Suffolk in 1910.

## TULARÆMIA.

Tularæmia is a plague-like disease which has been known since 1912 to affect jack-rabbits and other rodents, especially ground-squirrels, in California. Unfortunately it is communicable to man, in whom it causes an intractable illness.

Tularæmia [41] in man is a disease of the rural population, particularly in field workers, and is recorded amongst dealers who handle infected jack-rabbits. The organism, *Bacterium tularensis*, is not easy to cultivate on artificial media: it is extraordinarily infective and many laboratory workers have contracted the disease. The infection is transmitted, from one infected jack-rabbit to another, by a blood-sucking fly, *Chrysops discalis*.

The jack-rabbit (*Lepus campestris*, Bachman) is a very familiar species in America. It is a large hare-like creature with long hind-legs and ears. In the northern parts of its range its coat turns white in winter, but further south this change is partial, or does not occur. Like our hare, it lives in the open and depends for safety on its protective coloration, speed and acute hearing. For its home the jack-rabbit has an open form beneath a bush or clump of weeds. Large numbers of these animals are killed annually in drives, as many as 20,000 having been accounted for in one day.

The ground-squirrel (*Citellus grammurus beecheyi*), which also forms a reservoir of infection, is the same species as that concerned in the spread of plague in California.

The gophers (*Geomys*) form another source of infection. These are curious little animals, characterized by large cheek pouches opening outside the mouth, and they have feet with immense claws for digging. Their bodies are heavy and their movements slow and clumsy. Their habits are nocturnal and they live in communities in burrows. *Thomomys bottæ bottæ* (Eydoux and Gervais), which extends along the coastal region of California, is the species concerned.

## MELIOIDOSIS.

There still remains one more recently described glanders-like disease in man known as *Melioidosis* [42], which occurs in Burmah and the Malay States. The organism known as *Bacillus whitmori* occurs as a natural infection in the Malay rat (*Mus griseiventer*, Bonhote), which, in spite of its name, is the local representative of the common black *Rattus rattus*.

I have now summarized somewhat incompletely, I fear, the state of our knowledge regarding the wild animal reservoir hosts of human disease in the wilder portions of the earth. There still remains the helminthic infections that I do not propose to deal with in detail, but of which I append a list at the end of this paper.

There are other widespread and almost universal infections, such as malaria, in which the parasite, though indigenous in most parts of the tropics, is peculiar to man, and to man alone. Strange to relate, human malaria parasites have never been found in any other vertebrate host, not even in the larger apes which harbour, it is true, their own particular species of *Plasmodium*. From this circumstance I think we may fairly infer, from what we know of the natural history of other protozoal infections, that primæval man must have acquired his *parasite* from some reservoir host.

If it is usually considered permissible for ethnologists, dealing solely with his more durable remains, to speculate upon the heredity of man, so it is equally permissible for the parasitologist to speculate upon the probable evolution of man's diseases. It may be that the original reservoir host of malaria was some hoary and hairy simian anthropoid, one of the missing links long since extinct and whose bones lie buried deep in the alluvial earth of Central Africa. But though the anthropoid became extinct, his parasite did not and was transmitted as a sort of heirloom to his more intelligent and highly developed descendant—man.

But whence did these remarkable parasites arise, organisms which have such an intricate life-history? Did the malaria parasite first exist in the mosquito and later in man, or vice versa? Were the trypanosome and tsetse on intimate terms long before man was swinging in the tree tops of the great African forest? I fear that we have no very exact data upon which to base any reasonable hypotheses. One can readily understand how a free-living organism can readily adapt itself to the life of another animal (there are plenty of instances of this in Nature), but it is more difficult to explain how it can accustom itself to hosts so entirely dissimilar in structure and habits, as man and the tsetse, or man and the mosquito, and as to how the parasite came to lead the entirely different life-cycles within the vertebrate and invertebrate host.

Possibly the blood protozoa of man and animals were at one period parasitic in the latex of certain plants, and, through being constantly ingested by insects which feed on these juices, they eventually came to adapt themselves to a semi-parasitic existence within the alimentary canal of the insects. In course of time, and in process of evolution, the predatory instincts of a more adventurous bug led it to feed upon the warm blood juices of rodents and other mammals. Ingrained habits may change; thus the Kea parrot of New Zealand (*Nestor notabilis*) found the liver of sheep imported into that country more succulent than the acrid fungi upon which it was wont to feed. It may be so, by constant close association of insect with food supply, that the primitive parasite followed suit and came to pass part of its existence first in the one and then in the other.

Certain discoveries which have been made in recent years support this hypothesis.

Flagellates of the *Leptomonas* type, closely allied to leishmania, have been found by Lafont, Migone (1916), França (1921), and others, in the latex of plants of the genus *Euphorbia*; the second named observer has shown that a plant bug, *Stephanoccephalus agilis*, is responsible for the spread of infection from plant to plant in Portugal. The bug, which is nocturnal in its habits, punctures, while feeding, the leaf of the plant in many places and transmits the parasites through its salivary glands. Strong (1924) makes a stronger claim in stating that lizards which devour certain of these plant bugs acquire an intestinal infection with the flagellate, which then, he asserts, assumes pathogenic properties for monkeys.

Other flagellates which they closely resemble in structure inhabit the intestinal tract of house flies (*Herpetomonas muscæ domesticæ*), bluebottles and even biting flies.

From a morphological standpoint these free-living forms are indistinguishable from the evolutionary stages of trypanosomes and leishmania, the familiar blood protozoa of man.

It has been further claimed by some investigators, notably Laveran, Franchini, and Fantham, that vertebrates, particularly mice, may be easily infected with insect flagellates by inoculation or feeding, and that in some instances a diseased condition resembling kala-azar may result. But this work has not received the necessary confirmation, so that it is only by intensive research and numerous transmission experiments with these lowly forms of life that further light can be shed, not only on the origin of the parasites themselves, but also upon the chequered history of *Homo sapiens* himself.

I must acknowledge, as is only due, my gratitude for the generous assistance I have received in preparing this paper from Mr. M. A. C. Hinton, of the British Museum, Mr. Martin Duncan, of the Zoological Society, and Dr. Daukes, of the Wellcome Bureau.

#### LIST OF HELMINTHIC PARASITES FOUND IN MAN AND WILD ANIMALS.

##### TREMATODA:—

- Fasciola hepatica*. Wild ruminants, deer and antelopes.  
*Heterophyes heterophyes*. *Canis niloticus*. Egypt.

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### TREMATODA (continued).

- Paragonimus westermanii*. Tiger and leopard. India.  
*Schistosoma hæmatobium*. Sooty mangabey monkey (*Cercocebus fuliginosus*).  
*Schistosoma japonicum*. Rats (*Rattus*). China.  
*Gastrodiscoides hominis*. Mouse-deer (*Tragulus napu*). Malay States.

### CESTODA :—

- Cysticercus cellulosæ*, larval stage of *Tænia solium*. Wild boar (*Sus scrofa*).  
*Cysticercus bovis*, larval stage of *Tænia saginata*. Giraffe (*Giraffa camelopardalis*).  
*Hymenolepis diminuta*. Rats (*Rattus rattus*, *Rattus decumanus* and *Rattus alexandrinus*). Mice (*Mus musculus* and *Mus sylvaticus*).  
*Dipylidium caninum*. Jackal (*Canis aureus*).  
*Echinococcus granulosus*, larval stage of *Tænia echinococcus*. Wolf (*Canis lupus*).  
 Jackal (*Canis aureus*).  
*Sparganum mansonii*, the plerocercoid stage of *Dibothriocephalus mansonii*. Frog (*Rana nigromaculata*). Snakes (*Elapheclimacophora*). Japan.  
*Diplogonoporus grandis*. Various species of seal. Japan.

### NEMATODA :—

- Belascaris canis*. Fox (*Canis vulpes*).  
*Toxascaris canis*. Wild cat (*Felis catus*).  
*Ternidens deminutus*. Monkeys (*Macacus sinicus* and *Macacus cynomolgus*).  
 Nyasaland and Transvaal.  
*Physaloptera mordens*. (*Macacus sinicus*). Nyasaland.  
*Ancylostoma duodenale*. Tiger. India.  
*Ancylostoma ceylanicum*. Civet cat (*Viverricula malaccensis*). Ceylon. Clouded leopard (*Felis nebulosa*). Malay States.  
*Necator americanus*. Gorilla (*Gorilla savagei*). Patas monkey (*Cercopithecus ruber*).  
*Æsophagostomum apiostomum*. Gorilla. Orang-outang (*Simia satyrus*).  
*Trichuris trichiura*. Various old-world monkeys.  
*Hepaticola hepatica*. Rat (*Rattus norvegicus*).  
*Trichinella spiralis*. Wild boar (*Sus scrofa*).  
*Loa loa*. Baboon (*Papio cynocephalus*). West Africa.  
*Acanthocheilonema perstans*. Chimpanzee (*Anthropopithecus troglodytes*). West Africa.  
*Dracunculus medinensis*. Jackal and leopard.  
*Gnathostoma spinigerum*. Tiger. India. Puma (*Felis concolor*). South America.

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*Discussion.*—Dr. H. HAROLD SCOTT said he was a little surprised that such an important disease as rabies had not been mentioned, but naturally in a paper which had to be of limited length owing to time available, some omissions must be expected. He spoke of two interesting conditions which might, perhaps, be regarded more as common to man and animals than actually communicated from the latter to the former, though communication was quite possible. The first was a small epidemic he had investigated amongst the hamadryas baboons at the Zoological Gardens, in the course of which sixteen of them had died with intestinal ulceration. From twelve of these he isolated from the bile and from septicæmic abscesses in the lungs and the liver the *Bacillus aertrycke* which was the cause of severe and often fatal lesions in man. The second was the isolation of *Bacillus morgan*, No. 1, from two *Patas cercopithèques* recently dying from enteritis at the Gardens. This organism, as was well known, had been incriminated as one of the causes of summer diarrhoea of children—a disease commonly fatal.

(Communication to the Discussion made by letter dated January 19, 1926.)

Mr. EUSTACE MONTGOMERY (Nairobi, Kenya): I wish I could be present for Manson-Bahr's paper, but it is a combination, i.e., wild animals and man, of which I have no personal experience except our pseudo-rabies and trypanosomiasis. The former appears indeed not to be a "disease" of man and the latter could be discussed with advantage, but without finality, for days. What, however, might with advantage be brought out at the discussion is the great anomaly of "game" control in most of our tropical possessions. I am a keen "shikari" and advocate protection against extermination for many reasons, but as practised by a game "department," numbers and range of species are encouraged to expand, largely at the expense of man or his domestic stock. In such fortunate countries where there exist no diseases (contagious) of stock, and where grazing, water, &c., suffice for all, no harm is done. But in such as Eastern Africa, the veterinary departments, armed with very elaborate and often most penalizing "Diseases of Animals Ordinances," demand of a stock owner that he shall fence his land, brand his cattle, &c., inoculate them against various diseases and so on. In other words great restrictions are put on domestic mammalia in the interests and needs of disease control. In most countries, for example, no cattle can be taken from one village to another without a written permit specially obtained. Yet we encourage wild mammalia, lacking even the most primitive control of the most uncivilized natives' cattle, to roam at will without fences, permits, brands or inoculations. Wild and domestic are susceptible to the same great East African menace—rinderpest—and are naturally carriers and disseminators; and, without question, inquiry would disclose more than rabies, anthrax, swine fever, horse-sickness as between wild or domestic.

Both are susceptible mammals; oftentimes the wild is the greater menace, and yet for the sake of "protection," as well as revenue from licences to shoot, this extraordinary difference is made between the classes. Either the precautions now applied to the domestic are unnecessary or the freedom to the wild to roam and propagate is undesirable. In any case, it is illogical so to make fish and fowl of susceptible species of a common stock.

The remedy is not game destruction, as some would urge, but scientific game protection, as there is scientific stock protection, and this would also encourage inquiry into habits as well as diseases intercommunicable with man and domestic stock. We have many men ideally competent for such observation, and, if they do not want to be bothered to sell licences and to prosecute poachers, there are such departments as Revenue, Administration and Police quite well constituted for this everyday purpose.